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WEATHER AND OVERLORD: CONTEMPORARY LESSONS

By COLONEL GENE J. PFEFFER

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WEATHER AND OVERLORD: CONTEMPORARY LESSONS

by

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A RESEARCH REPORT SUBMITTED TO THE FACULTY
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Research Advisor: Dr. Joseph Strange

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AUTHOR: Gene J. Pfeffer, Colonel, USAF

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BIOGRAPHICAL SKETCH

Colonel Gene J. Pfeffer (M.S., St. Louis University, M.S., Western New England College) has worked in the field of meteorology for a large part of his Air Force career. After attending weather training at the University of Utah, he was assigned to the Air Force Eastern Test Range as a Staff Meteorologist. He later held various staff positions within Headquarters, Air Weather Service. He commanded the weather detachment at RAF Bentwaters in England, and was assigned to the Electronic Systems Division at Hanscom AFB. From 1979 to 1983 he was assigned to the Directorate of Operations on the Air Staff as Program Element Monitor and Chief of Weather Programs. His most recent assignment was Assistant Deputy Chief of Staff for Systems for Air Weather Service. Colonel Pfeffer is a graduate of the Armed Forces Staff College and the Air War College, class of 1985.

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CHAPTER I

INTRODUCTION

In the period after Hitler's conquest of Europe and after the Pearl Harbor attack, the Allies faced a world in crisis, threatening the very existence of a free Atlantic community. Momentous decisions were to be made which would determine the future of the great democracies. OVERLORD, the cross-Channel attack which hit the Nazi-occupied beaches of Normandy in 1944, was the culmination of a grand strategy adopted early in the war, followed sporadically during the years of conflict, and aimed at defeating Hitler's Reich by striking directly at Germany by invasion. As such, it was the culmination of a long series of difficult strategy negotiations among the Allies, ultimately setting the stage for final victory. For the Anglo-Americans OVERLORD was the decisive campaign of the European Theater.

The Allied invasion of Normandy on 6 June 1944 represents one of the most monumental weather-sensitive military operations ever undertaken. The planners and decision makers required weather assessments and forecasts in order to bring off such a huge operation successfully. The actual weather constraints for the invasion were critical and complex. Air power needed clear skies to be effective. Naval forces needed calm winds and seas. Airborne forces wanted low winds for their drop but also clouds to hide them from the Germans. In 1948 General Eisenhower, the Supreme Allied Commander for OVERLORD,

described the problem this way:

We wanted to cross the Channel with our convoys at night so that darkness would conceal the strength and direction of our several attacks. We wanted a moon for our airborne assaults. We needed approximately forty minutes of daylight preceding the ground assault to complete our bombing and preparatory bombardment. We had to attack on a relatively low tide because of beach obstacles which had to be removed while uncovered. These principal factors dictated the general period; but the selection of the actual day would depend upon weather forecasts. (1:239)

These factors presented Allied meteorologists with a very difficult, vitally important task at a time when the scientific state of the art was quite limited. There were no weather satellites, no weather radars, no sophisticated computer forecasting techniques, and no large network of stations providing upper air data critical to longer range forecasting. Despite these limitations, the Allied weather team was imminently successful. The dramatic success story of the OVERLORD weather forecasts has been told in several excellent accounts (FORECAST FOR OVERLORD being the most notable) and, with the exception of brief references, it will not be recounted here. Instead, this report will focus primarily on the process and not the result. The organization and functioning of the supporting weather services (organizational arrangements, command lines, scientific state of the art, use of weather intelligence, etc.) will be examined to establish the foundation for lessons still applicable to contemporary military operations.

CHAPTER II

AN OVERVIEW OF OVERLORD

Before its launching, the invasion of France looked to be a most hazardous undertaking. Allied troops had to land across open beaches on a coast that the enemy had been fortifying for four years. The German Army had fifty-eight combat divisions in the West, ten of which were armored divisions whose shock power could throw the Allied invasion back into the sea. The Allied ability to match the power of the German Panzers on D-Day and thereafter was severely limited by the availability of landing craft and ports. The initial assault was limited to six divisions from the sea and three from the air. Weeks would pass before reinforcements could double the nine divisions put ashore on D-Day. (2:543)

Nevertheless, the Allies soon expanded their initial small beachhead and the Germans failed to deliver their expected counterattack. When Allied armor broke out of the bridgehead on 24 July 1944, more or less according to pre-D-Day planning, the entire German position in France collapsed. Ten months after D-Day, Hitler had committed suicide in a Berlin bunker. (3:425-478)

In retrospect, one is tempted to view the success of OVERLORD as a foregone conclusion. In reality, the margin between success and failure was slim. The Allies were in great danger of the disaster that they so feared. Victory

eventually came because of the overwhelming Allied logistical base, unchallenged airpower, and grave German strategic mistakes. But the success of the initial assault was the crucial ingredient. (4:11-12)

The fundamental military problem with the OVERLORD assault was to establish and maintain a reasonable margin of local superiority over the enemy. The assault plan, called NEPTUNE, was vital and complex. Five hundred warships and 3,000 landing craft were needed for the initial assault alone. The U.S. and British Navies provided, assembled, and escorted the invasion fleets, kept the Channel open, and provided effective onshore bombardment. (5:24) Yet, insufficient shipping existed to develop a flow of troops and supplies across the Channel to match what the Germans could bring to bear if they were allowed to marshal forces unmolested. (6:75) This is why Eisenhower put so much emphasis on an air campaign to cut potential reinforcement routes. It is also why the Allies undertook a massive disinformation campaign to deceive the Germans as to the actual landing area, holding many of the best German divisions in the vicinity of Calais. (4:63)

The plan for the post-D-Day land campaign consisted of several phases: solidifying and expanding the beachhead; securing the port of Cherbourg; and breaking out of Normandy into Brittany to seize the Atlantic ports and to envelope the German Army. During this latter phase, the planners envisioned powerful British and Canadian thrusts in the Caen

sector while the U.S. First and Third Armies broke through the southern portion of the front. (5:24) OVERLORD was, upon analysis, a near run thing. But Eisenhower correctly counted on airpower, intelligence, and surprise to even the odds.

CHAPTER III

THE WEATHER SUPPORT STRUCTURE FOR OVERLORD

World War II demonstrated the need for an adequate weather service for the military and made it an indispensable part of combat operations. Two factors accounted for this. The first was the extensive use of airpower which was highly weather dependent. The other was the high premium placed on both the strategic and tactical application of mobility. It was to be a war of blitzkrieg, aircraft, and armor. The lessons of World War I had been learned by both sides. Therefore, no commander worth his salt would commit forces without considering the effects of weather on his operations.

The invasion of Europe constituted a combined operation on a scale which had never before been attempted and involved all the Services of the United States and Great Britain. Therefore, it was necessary to establish an organization for providing weather services to the Supreme Commander and Component Commanders concerning operational decisions about the invasion. Besides providing the best possible advice, it was necessary to insure complete coordination so that decisions at all echelons were based on the same weather outlook.

Three months before General Eisenhower arrived in England to take over as Supreme Commander, U.S. and British authorities discussed the part to be played by

meteorologists in OVERLORD. Of immediate importance was the development of a single, all-encompassing climatological assessment about the period of the year when weather conditions were most likely to be favorable. (7:11) The Chief of Staff, Supreme Allied Commander (COSSAC)(soon to become Supreme Headquarters Allied Expeditionary Force (SHAEF)), British Lieutenant General Sir Frederick Morgan, wanted an independent weather officer to develop the assessment and to advise the Supreme Commander at the time of the invasion. In order to conform to the Anglo-American nature of Morgan's combined staff (his G-3 was an American, Major General Harold R. Bull), two meteorologists, one U.S. and one British, were to be appointed under the G-3. The senior post was to go to a British Group Captain while his deputy in turn was to be a Colonel from the U.S. Army Air Force (USAAF) Weather Service. (8:5-45) A civilian meteorologist from the British Meteorological Office (BMO), J. M. Stagg, was appointed to the senior post. Colonel Tieman of the USAAF was named his deputy although he was soon to be replaced by Colonel (later Lieutenant General) Donald Yates.

The selection of the weather team did not come without controversy. U.S. Army officials in England were not pleased with the appointment of a civilian to the top post. This led Lieutenant General Walter Bedell Smith, Eisenhower's Chief of Staff, and Air Chief Marshall Sir Arthur Tedder, the Deputy Supreme Commander, to apply

pressure, successfully, to the British Air Ministry to at least frock Stagg as a Group Captain in the Royal Air Force(RAF), giving him the rank and professional stature needed to work in the secret, high-level military circles associated with planning for OVERLORD. (8:45)

Though not an experienced operational forecaster, Stagg was a capable meteorologist and well qualified to do his job of pulling together the forecast and presenting it to Eisenhower and his subordinate commanders in a manner which they could use for military operations. (9:82) His American deputy, on the other hand, was an experienced operational Air Force pilot who had been trained in meteorology at the California Institute of Technology (Cal Tech). Yate's appointment to the COSSAC staff dual-hatted him since he was already the senior USAAF weather officer in the European Theater. General Bull instructed him to provide interpretations relating to weather forecasts and their operational implications for Army and Air Force units. (9:82)

There were already in England three major Allied weather facilities (called weather centrals or centers) supporting the various service subordinate components. In conformity with the need to keep the SHAEF team small it was decided that Eisenhower would be briefed only by Stagg and Yates who would synthesize the data provided by the various weather centrals. (7:8) The weather centrals were the major sources of meteorological expertise for their

component or Service (USAAF, Royal Navy, etc.). They performed the large-scale weather analysis and forecasting functions for operations. In contrast, weather stations at each base provided local weather observing, takeoff and recovery forecasts, and briefed the mission and target weather provided by the centrals.

To accomodate Stagg and Yates, a special encrypted telephone system was established to permit frequent conferences among the various weather centrals and staff weather officers then operating in England. (10:1) Participants in this network included the BMO forecasting unit at Dunstable (primarily supporting the RAF), the British Admiralty Weather Central in London, the USSTAF's Weather Central at Bushy Park (code name Widewing), the Staff Weather Officer to the Air Commander-in-Chief at Stanmore, the Staff Weather Officer to the Naval Commander-in-Chief at Southwick, and Stagg and Yates at SHAEF. (10:1)

The USAAF's 18th Weather Squadron had been established in England in July 1943 to support the Eighth Air Force. Its weather stations were scattered among the various divisional and combat wing headquarters, operational group headquarters, and at certain Air Transport Command bases. Its mission of supporting strategic bombing dictated that it operate from fixed facilities with fixed equipment. By January 1944 it numbered 244 officers and 429 enlisted. In the fall of 1943 the newly established 21st Weather

Squadron arrived in England with a strength of about 600 men at 37 detachments. It was organized and equipped in a mobile configuration to support the tactical aviation which would eventually move to France after the invasion. The 18th and 21st Weather Squadrons, nominally independent of each other, together made up the bulk of the USAAF Weather Service in Europe during 1943 and 1944. (11:4-9)

As Allied forces began to gather in England for the coming invasion, fighting units and their supporting headquarters expanded greatly. In January 1944, the Headquarters of the United States Strategic Air Forces in Europe (USSTAF) was created and put under command of Lieutenant General Carl "Tooe" Spaatz. USSTAF assumed control of both the Eighth and Ninth Air Forces. (12:104)

The Army Air Force undertook a coordinated expansion of weather support in England in early 1944 by establishing a forecasting central and overall administrative headquarters known collectively as the USSTAF Directorate of Weather Services. Both the Directorate and the USSTAF Weather Central which it included were under the direction of Colonel Yates. He had been sent from the Headquarters Army Air Forces weather facility in the Pentagon and was the senior U.S. weather officer in Europe. (13:13-14)

According to Yates, General Henry "Hap" Arnold, Chief of the Army Air Force, personally told him about the Eighth Air Force and his future assignment to USSTAF before he left Washington.

...Their bombers are getting weathered out. They can't get back in. They have lost more bombers that can't get back in than they have lost to enemy fire. There is something wrong with the weather service over there. I told Tooey [General Spaatz] that I was going to send the best weathermen in the Air Force...I want you to organize a group of any forecasters you want ...and take them over and report to Tooey Spaatz and do it in two weeks. (9:69)

Yates took Lieutenant Colonels Ben Holzman and Irving Krick as the Chief Forecasters for the new central and Captain Robert Bungaard as the chief upper air analyst. Both Holzman and Krick were experienced in peacetime and wartime weather services and were among the foremost practitioners of long range weather forecasting in the United States before the war. Bungaard had been schooled in the relatively new techniques of upper air analysis and prediction which were key to extended range forecasts. Colonel Yates himself had previously served in weather posts in Headquarters Army Air Forces and had won the Distinguished Service Medal for leading the U.S. Meteorological Mission to Moscow during 1942. (13:15-16)

The USSTAF Weather Central furnished weather services in support of Eighth Air Force strategic bombing missions, Ninth Air Force tactical operations, SHAEF invasion preparations, and the Headquarters, USSTAF decision makers. Its activities were concerned with tactical and strategic targeting, take off and recovery weather, reconnaissance coverage, winds aloft, and the myriad of other weather interests of a fighting air force. The central was also involved with trafficability estimates for Army

vehicles, smoke screen effectiveness studies, and similar issues. (13:18-29)

During the invasion, the first U.S. weather personnel to reach France jumped in with the 82nd and 101st Airborne Divisions at 0100 hours on 6 June. They belonged to the 21st Weather Squadron. These were followed by weather personnel assigned to air support parties in jeeps and half-tracks who went ashore with the first assault troops. Larger weather detachments supporting ground and air units began arriving on D+1. (11:32-34)

On the British side, the BMO was at this time a department of the Air Ministry. It controlled weather services to both the British Army and the Royal Air Force and was closely linked with the latter. In contrast to U.S. practice, the British meteorologists were civilians who were temporarily commissioned when they served overseas with the military forces. (7:8)

The British central at Dunstable was represented in the OVERLORD period by Douglas and Petterssen. Douglas had served extensively in World War I as a pilot and weather observer. As a professional meteorologist since the war he had become an expert in weather over England and Northern France. Petterssen had been a weather expert in Norway before taking a university teaching position in the U.S. He had a deservedly high reputation as a leading theoretical meteorologist. (7:53-54)

According to Stagg, the forecasters at the Admiralty

center normally accepted the weather forecasts from the BMO center at Dunstable. Throughout the course of the OVERLORD operation they did not contribute substantially to the development of the overall forecasts other than by interpreting the weather patterns in terms of sea state and swell for naval operations. (7:55)

CHAPTER IV

REQUIREMENTS AND PROCEDURES

One of the valuable contributions meteorology can make toward long term planning for a large scale operation is the use of climatology to bound the problem, i.e., the likely range of expected weather conditions for the time and place of the operation. When Stagg arrived at COSSAC in November 1943, he found that a large amount of climatic data had been acquired and summarized for the coast of France and the Channel. But most of the data had been derived from different historical periods and had been analyzed using different procedures--some of questionable validity. Moreover, each planning group had imposed its own operational limits on the conditions essential for its specific part of the operation. The not surprising result was that many different conclusions were being drawn about the best place and time for the invasion. (7:12-16)

Stagg's first important task, therefore, was to establish in concert with the planners a more precise list of acceptable weather conditions for the invasion so that both the climatological and operational weather analysis would be responsive to the needs of the Supreme Commander. Stagg used this analysis to refine the climatic assessments needed by the SHAEF staff for planning, and later used these criteria to shape his weather forecast presentations to Eisenhower and the staff. (7:12-15)

The specific approach for the operational D-Day

forecast itself (as opposed to the long range climatic expectations) was established by Bedell Smith. He asked Stagg and Yates to prepare five-day forecasts for Southern England and the French coast and to present them to Eisenhower each Monday morning. Eisenhower needed to know four days before the D-Day target date if weather would preclude an invasion attempt. Good conditions on D-Day itself would be of little use if poor weather during the three or four preceding days precluded essential air and naval preparations. The same could be said for the period following the landings. It would be of little good to successfully forge a beachhead on Fortress Europe on D-Day if unfavorable weather prevented the necessary build-up and resupply of forces. At a meeting with his senior staff and the two SHAEF weather officers Eisenhower personally reinforced the point:

...when the time comes to start Overlord we are going to have to rely very much on the weather forecast, so I want to hear what our weather experts can do. Each Monday until then Group Captain Stagg will tell us what he thinks the weather will be for the rest of the week, and on each following Monday he will tell us how his forecast has worked out. We'll have a check on that part from our own experience. For these weekly exercises D-Day will be Thursday. Now Stagg, go ahead. (7:46)

In addition to the D-Day forecast itself, the services of Yates and Stagg were required in support of various operations preliminary to the invasion which were continuously underway during May and June 1944. For example, the Allied Air Forces engaged in an extensive

campaign against the rail and bridge transportation system in France to hinder the deployment of German reserves against the invasion, and naval and ground forces conducted many large-scale amphibious exercises along Britain's southern coast. Weather support for these operations was provided by the various component centers, and each day's weather forecasts had to be coordinated among the staff weather officers to insure compatibility of operational decisions. Stagg and Yates became involved in these activities when there was direct interest among the SHAEF staff. (13:4)

The weather conferences among the centrals started in February 1944, at first on a two to three times per week basis. From April onward the conferences were held each day. For the larger exercises and operations, and as D-Day itself approached, the number of conferences was increased to three a day: 1) a preliminary conference in the late afternoon to coalesce initial thinking among the centers on the next five days; 2) the main conference in the late evening to agree on the main features for the five-day outlook; and 3) an early morning conference to modify as necessary based on the latest data. On the days immediately preceding D-Day a further conference was held at 0300 each morning to prepare for the Supreme Commander's meeting at 0430. Each of the conferences lasted about an hour although some exceeded two hours. (13:4-5)

The official SHAEF post-OVERLORD report of weather

operations describes the procedures used to develop the forecasts and advice for the Supreme Commander as follows:

The chair was taken by the Meteorological Officer on the Staff of the Supreme Allied Commander and the discussions were opened either by the Air Ministry, U.S. Weather Service, or by the Admiralty in rotation. When these three "centrals" had expressed their views, the conference was more or less thrown open to general discussion, in which all points of difference were fully examined, and if possible eliminated, and in which the Staff Meteorological Officers had the opportunity to raise any points which might have been overlooked and to elucidate information of particular importance to the Naval, Army, and Air Staffs. Finally the forecast was drawn up by the chairman and submitted at the conference to all concerned, for their approval or otherwise. (10:1)

This is a rather sterile description of a process which, during the difficult days immediately preceding the invasion, on many occasions took on characteristics of a knock down, drag out fight among strongly opinioned professionals. Each had the highest of motivation, each was convinced that his vision of the future weather in the Channel was correct, and each knew the incalculable cost of bad advice to the Supreme Commander.

Strong personalities were involved in the weather problem. Petterssen and Krick often clashed over the current and future course of the weather situation to the point that Stagg considered asking the British central on one hand and the U.S. central on the other to stagger the work schedules of these "primadonnas" so that their unnecessary arguments could be kept out of the forecast sessions. (8:5-47)

CHAPTER V

THE STATE OF THE SCIENCE

By the standard of the times the weather data base available to the OVERLORD meteorologists was extensive. There was a relatively large network of surface weather observing stations throughout North America, across Greenland, and into the British Isles. In Britain, upper air observations were made at several locations four times per day. In North America, they were available twice daily. There was extensive RAF weather reconnaissance over the ocean. West of the British Isles there were two Allied weather ships that made upper-air balloon soundings. There were also delayed weather observations from ferry flights across the North Atlantic. (15:4-5) The Army Air Force Directorate of Weather in the Pentagon provided coded upper air analyses of North America and the North Atlantic to the USSTAF central twice daily. The British central at Dunstable completed its own, more limited upper air analysis. (15:6-7)

From these sources, the USSTAF central developed its forecasts. Every six hours weather officers analyzed storm and pressure patterns for the surface and three upper air levels. (13:18-26; 15:5) Once the analyses were complete, several methods were used to develop the forecast.

One tool used by the USAAF centrals was the extensive climatological records for Europe. When analyzed,

these records provided some statistical assessment of the most probable conditions for a given location, time, and season. (13:28)

The most widely used technique was the analogue method. This approach attempted to find a weather situation in the past which was similar to the present day's weather patterns and use it to make a forecast assuming that the weather which followed the previous situation would repeat itself. This technique was based on a file of forty years of past weather charts. (16) It consisted of a compiled index catalog of all weather patterns which covered the northern hemisphere each day for as many years as possible. These patterns were then cataloged according to the weather type dominant in each area. The actual process of forecasting depended on being able to select quickly from the catalog the particular pattern from past history which most closely resembled the current one and assuming the pattern which had followed it would repeat itself. Much of this work was originally done by Knick and his associates at Cal Tech and used the early IBM machines for sorting punched card data. (7:22)

Altogether there were four main techniques for making long range forecasts out to five days. These included: 1) an analogue technique developed by J.J. George while working for Eastern Airlines predicting aviation weather; 2) Knick's analogue technique described above; 3) a complex technique based on repeating periods of weather and

analogues; and 4) a statistical method which extrapolated the previous movement of weather features five days ahead. (15:3)

Central meteorologists developed each day's forecast for military operations by using the analyzed weather charts to define current conditions, using the climatic data given current conditions to indicate the most probable future conditions, and by using the deviations from current conditions indicated by the forecasting techniques. (16)

For his part, Stagg believed that reliance was placed on the other techniques only to the extent that they supported Knick's analogue procedure. (7:30)

At the Dunstable central, things were different. The forecasters there had no objective techniques for longer range forecasts. They were using the new upper air analysis techniques to produce a relatively short extension to the normal 24-36 hour forecast by extrapolating surface weather features ahead using the upper air steering winds. (7:30)

The American view was that useful long range forecasts could be routinely produced. In contrast, the British forecasters did not believe that such long range forecasts were reliable. They depended on relatively short range extrapolations of current weather conditions since their experience had showed them the volatility of weather conditions in the British Isles. The British did not believe that the U.S. forecasts for Britain were accurate beyond one or two days. Thus, the British forecasters at

Dunstable were averse to looking beyond a few days in their forecasts. Stagg was particularly wary of the analogue techniques since, in his mind, no two weather situations were exactly alike. He felt that his own verification studies showed the extended period forecasts beyond the first few days to be wrong as often as they were right. (7:19-23,32)

Stagg did realize however that he must provide some outlook for the Supreme Commander. This dichotomy was a source of friction throughout the period preceding the operation. The U.S. forecasters were willing to make an estimate of the longer range picture while the British were reluctant to do so. (7:21)

CHAPTER VI
SECURITY, INTELLIGENCE, AND COMMUNICATIONS
SECURITY

The security of weather information was one of the most difficult problems for Allied weather services after the outbreak of the war. This was especially true for the European theater since weather generally moves from west to east. Weather data from North America and the Atlantic were important to both sides. But the Allied centers in England had a distinct advantage over the Germans in weather forecasting since the Allies controlled the Atlantic approaches. From the defensive point of view it was necessary to deny the Germans knowledge of weather in Britain as it would help their bombing of Allied bases. For offensive operations it was important that the Germans knew as little as possible about future weather over the continent so that they could not forecast where Allied bombers would strike or draw accurate conclusions as to favorable invasion weather. Thus, all Allied weather data was enciphered prior to transmission to prevent interception. (13:34-35)

The protection of weather data was not without its drawbacks. The problems associated with enciphering and deciphering weather messages manually was a large factor in delaying receipt of most weather data to the forecaster. In addition, encoding errors frequently led to erroneous data

being used in the analysis and forecast. These factors inevitably affected the precision of operational forecasts since forecast skill decreases significantly with the "age" and inaccuracy of weather data. (13:34; 7:42)

INTELLIGENCE

The breaking of the German codes also provided additional weather data and weather-related information valuable to the Allied cause. One intercepted ULTRA message in the last hours before D-Day provided welcome confirmation that the Germans did not expect the forthcoming invasion. It was a decryption of the Luftwaffe's nightly weather outlook. The Luftwaffe meteorologists predicted that disturbed conditions would persist in the English Channel throughout the current phase of the moon and tides. This confirmed that the Germans had not detected the brief interval of improved weather that Stagg's consortium had predicted which allowed the invasion to go forward. (17:634)

ULTRA would also help in the eventual destruction of the German weather intelligence gathering system. Accurate weather forecasts were important to the Allies and Germans alike. Decrypted weather reports gave away the positions of German weather stations on Greenland and weather picket U-boats patrolling the Atlantic which were then systematically captured or destroyed by the Allies. According to Anthony Cave Brown, "of all the natural

factors, of all the schemes of men, that would unfold to influence the success of the invasion, Allied knowledge--and German ignorance--of weather conditions on D-Day would prove to be the most important." (17:670-677)

In spite of the Allied activities to limit German access to weather data there was some toleration when it served Allied interests. Almost daily Luftwaffe weather reconnaissance flights out of Brest and RAF Lancasters flying from St. Mawgen would meet over the water, saluting each other with wing dips. (15:4) Since both sides' weather reconnaissance flights were equally vulnerable, neither side took action against the other.

COMMUNICATIONS

To operate effectively, weather centrals must have rapid, reliable communications. Weather data are perishable. The older the data, the less useful it is for forecasting purposes. Data from North America, Greenland, Iceland, U.S. ship reports, pilot reports, and certain other data flowed by radio to a BMO facility at Prestwick, Scotland, where they were relayed to the BMO central at Dunstable and the USSTAF central at Widewing. Irish data, routine weather reconnaissance, and British ship reports went directly to the Dunstable central and Widewing. Data from the Soviet Union and the Mediterranean went to the USSTAF central and were relayed to Dunstable. Landline teletype was the primary communications medium within the

U.K. itself. (18:4)

Weather communications during the OVERLORD period were generally reliable and effective until the major headquarters moved to France after the invasion. It was at this point that major difficulties arose because of disruption due to unit movements. Soviet data were inadequate during the entire period because they did not include upper air observations and because of the delay in getting reports to the U.K. (18:5)

CHAPTER VII

THE D-DAY FORECAST

As recounted earlier, the process for arriving at the important D-Day forecast was difficult and filled with tension. The account which follows centers primarily on the results of the process as presented by Stagg and Yates to the principals, but some view of the human interactions involved comes through from the eye-witness accounts.

D-Day was initially set for Monday, 5 June, 1944. This was the earliest possible date for the invasion. Postponement might be permitted from day to day because of adverse weather until the 8th. After this date, any postponement would last for at least two weeks until the next period of favorable tides and moonlight. (13:39)

The weather situation as presented to the Supreme Commander and his Commanders-in-Chief for Air, Ground, and Naval Forces on 1 and 2 June was characterized as complex and changeable. Unsettled, winter-like conditions were going to make the "go" decision difficult. There was little hope for an ideal day. Great differences in outlook among the forecast centrals during the rapidly developing weather situation did not build confidence among Stagg and Yates that their advice would be of great value to the Supreme Commander, but these differences were not raised to Eisenhower. (7:68-89)

The USSTAF central, represented by Krick and Holtzman, was generally optimistic. They believed that the

strong high pressure system then in place over much of the region would keep the Atlantic storms north of the area of operations. The British central, represented by Douglas and Pettensen, was pessimistic, believing that the high pressure system would break down, allowing the storms to move through the Channel. (7:86)

Stagg, favoring the British view, briefed the Supreme Commander on Friday evening, 1 June, that conditions did not look favorable for an assault on 5 June, but that the situation was not at all clear. Eisenhower decided that even with a slim chance for favorable conditions on the 5th that he would start the bombardment fleet toward the French coast since it could be recalled if conditions deteriorated. These ships required considerable time to get into position. (7:80-89; 13:39-40)

On Saturday, 3 June, the outlook was definitely unfavorable. On Saturday evening, Stagg briefed that a cold front and low pressure system would move into the area increasing winds to above the 18 knot maximum on Sunday. There was little chance that cloud conditions would permit air operations on the morning of 5 June. Based on this outlook, Eisenhower postponed the operation until Tuesday, 6 June or Thursday, 8 June. If it couldn't go then, he would postpone it for 10 or 12 days. (13:40)

During Sunday, 4 June, the weather situation in the Atlantic began to clarify. The "Azore's high" which had been protecting the British Isles was breaking down.

Significant periods of unacceptable weather could be expected in the Channel throughout the week. If the invasion were to be launched at all, it would have to be done under the less than ideal conditions which would occur between the fronts that would transit the Channel. On Sunday evening, Stagg advised Eisenhower that a break in the weather would occur on Tuesday, 6 June. Winds would be 12 knots or less on the beaches, and cloud conditions would permit airborne and bomber operations. Eisenhower, with the concurrence of his staff, decided to proceed. At a final conference at 0400 on Monday, 5 June, they confirmed their decision. (7:10v-115)

Yates characterized those last hectic hours before the final decision this way.

By that time we had moved down to Portsmouth so that we were operating in Eisenhower's tent camp in Portsmouth....We were either on the telephone in conference, or we were in conference with Eisenhower and his commanders because they were running us. We would come on in, make another presentation; they would weigh it, and they would question it, and then they would weigh it. They would look at the weather, raining like hell...The morale was low. It was a disagreeable situation. We came up to the final meeting. It either had to be scrubbed, or it had to go. It was touch and go.

It was clear that there was going to be time in between two fronts. It was also clear that it wasn't going to be an absolutely clear night for bombing, and it was going to be kind of rough in the Channel... They asked for figures, 'Well, what's the chance of bombing visually?' I said, 'It's 50-50. I can't give you any more than that. You probably will get half of your bombers to see the targets. The other half will have to bomb by radar.' 'The paratroopers?'...'You will probably have half of them on your target and half of them scattered.' 'How about the sea?' 'It's over your limits.' Eisenhower turned to Ramsay [Commander-in-Chief Naval Forces] and said, 'Is that going to bother you?' He said, 'Hell, no. I will get

them on the shore.' He turned to 'Monty' and said, 'It's going to make a lot of people seasick going over on that rough stuff.' [Montgomery said], 'they are not going to be seasick. They are so drugged that they won't know which end is up. Don't worry about it. As far as I am concerned, the men can operate when they get ashore...' Then Spaatz and Tedder discussed the visual bombing versus the radar bombing. So Eisenhower said, 'I say we go. Any comments?' There wasn't a comment around the table. So they went. (9:86-87)

The actual weather on 5 and 6 June was much as forecast by Stagg and company. On the fifth, a storm moved through the Channel bringing unacceptable weather and high winds which would have been catastrophic to any landing attempt. On 6 June the weather was acceptable. No major difficulties were encountered by the naval forces except for problems with some landing craft and amphibious tanks, primarily in the more exposed American sector. Airborne and glider troops went in as scheduled. Fighters and medium bombers operated successfully from about 4000 feet. The heavy bombers had to bomb on instruments. (13:40-41)

CHAPTER VIII

CONCLUSIONS

When reviewing weather support to the OVERLORD operation one is struck by the enormity and difficulty of the task facing Stagg, Yates, and their cast of supporters and the magnificent job they did under trying circumstances. Yet, beyond the drama of the events themselves, as with all military history, there are lessons applicable to today's major military operations.

The most glaring problem concerned the organizational arrangements and command structure for weather support at SHAEF. There were major inherent defects in these arrangements which, at a minimum, unnecessarily complicated support and could have detracted from the operation under different circumstances. First, the necessity for consensus forecasts among the primary centrals severely complicated the forecast problem. So long as accurate weather forecasting involves some degree of subjective analysis and interpretation, conferences among centrals using different techniques and procedures will not easily yield agreement during complex weather situations. This is especially true in wartime situations when the normal amount of weather data will be reduced due to communications problems and data denial by the combatants. Denial has occurred in every major conflict in the 20th century.

A second major problem was the need for disseminating the coordinated forecast to the operational level. The forecasts provided to the operational forces must not conflict with that given to the overall commander making the primary decision, and must contain greater detail with regard to timing, location, and intensity of specific weather factors. To get agreement on this level of detail between different centrals in a timely fashion was an impossible task.

One way to overcome these difficulties is to establish a combined tactical weather central responsible for the major forecast decisions for large operations. Such a combined tactical central should be subordinate to the staff weather officer at the highest level of command directly involved and should include the best and most experienced forecasters of the various national weather organizations concerned. It should receive all the products and necessary supporting data of the various national weather centrals. Its mission control forecast would constitute the single authoritative forecast for operational decision making at the highest levels.

Yates generally shared this view. He said, "...I would never attempt to do a forecast that way again in my life. Pull the talent together," he advised, "and put them in a room and have them come out with a forecast, not three forecasts. That was a tough, tough period, but it worked, and we got away with it." (9:88)

Another difficulty which surfaced during the OVERLORD period was the tendency for decision makers to press forecasters to the limits of the science. While the Supreme Commander had a definite need for a long term forecast, there was insufficient capability to meet this need. Stagg's verification studies of the five day forecasts used in the April and May run-up trials showed that even in abnormally stable weather the operational value of the forecasts fell off quickly after the second or third day. When the weather situation was complex, forecasts were useful for about one day at a time. (14:20)

To Stagg's great credit he resisted the natural tendency to go too far out on a limb, even for good and valid requirements, when the state of the science would not permit it. At one point during the process Eisenhower pressed Stagg hard for a long term outlook. Stagg was reported to have responded: "If I answer that, Sir, I would be guessing, not behaving as your meteorological advisor." (7:88) Such problems continue to exist today, in spite of the great strides that have been made in meteorology since 1944. It is incumbent upon the meteorologist to know the limits of the science and to advise the commander accordingly.

Another problem concerns the timing of weather support for a large and complex operation. The weather section at SHAEF was set up a considerable time after the initial plans for OVERLORD had been made. Even after it was

established, as near as a month before the invasion it received few requests for support. (14:18) It is absolutely essential that military weather personnel be in at the initial planning for operations. Sometimes the greatest impact the meteorologist can make is in the selection of seasons, times, locations, tactics, weapons or force structure based on essential weather criteria. This must be done early before the operation takes on an unchangeable momentum. Today in the U.S. military, weather officers are assigned at all levels involved in planning and execution of major operations. It is imperative that they be brought in early, regardless of the security or the mission.

A related problem is the degree of access given the meteorologist to operational details. Even after the assault had been launched, Stagg did not have a coordinated list of weather criteria essential for the operation. He did not know until the weather situation began to look marginal that the airborne forces could operate in overcast conditions below 1000 feet. (14:18) Without full and complete access, contributions will be less than optimum.

One of the factors which comes through clearly in examining the forecast process is the vital importance of weather data necessary to developing weather advice for the Supreme Commander. In those days it came from land stations, ships, and aircraft. Today, weather satellites are taking an ever increasing role in acquiring weather

data. Both the superpowers, along with other nations, operate polar orbiting and geostationary weather satellites which their major weather centers rely on. Just as in the Overlord period, if conflict erupts, data will be denied and data acquisition systems will become targets. Our planning must confront this threat. Redundant systems, jam-proof communications, anti-radiation hardening, and data denial are all factors that must concern us in today's environment.

With regard to the operational commander himself, there are lessons from the D-Day operations. First and foremost, the commander should recognize the contribution of the meteorologist to the success of the mission. He is a source of intelligence just as important in certain aspects as the disposition of enemy forces. Second, as in all other aspects of an operation, trial exercises help uncover problems and solutions. It is important to play real weather problems in exercises to insure both that the command and control system can cope with real weather limitations and that potentially adverse outcomes have been considered in planning. Only through such exercises can it be determined which weather criteria are really limiting and what alternatives are available in the worst cases.

These are all important lessons which can be learned or reinforced from a study of the OVERLORD operation. But the most important lesson is OVERLORD's success. Under trying conditions the largest air-sea invasion in history was successfully launched in a short, relatively calm

interlude of a generally adverse weather pattern. It is a tribute to Stagg, Yates, and the men and women who supported them.

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GLOSSARY

BMO	British Meteorological Office
Cal Tech	California Institute of Technology
COSSAC	Chief of Staff Supreme Allied Commander
D-Day	Date to commence landing operations
D+1	One day after the start of operations
G-3	Deputy Chief of Staff for Operations
OVERLORD	Code name for the invasion of Europe
NEPTUNE	Code name for the naval portion of OVERLORD
SHAEF	Supreme Headquarters Allied Expeditionary Force
USAAF	United States Army Air Forces
USSTAF	United States Strategic Air Forces Europe